DRY VERSUS WET AGING OF BEEF: RETAIL CUTTING YIELDS AND PALATABILITY EVALUATIONS OF STEAKS USING ALTERNATIVE CUTTING STYLES

A Thesis

by

AMANDA MARIAN SMITH

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Approved by:

Co-Chairs of Committee,	Jeffrey W. Savell
	Kerri B. Harris
Committee Member,	Davey B. Griffin
Head of Department,	H. Russell Cross

December 2012

Major Subject: Animal Science

ABSTRACT

Boneless ribeye rolls (*n* = 12) and boneless top sirloin butts (*n* = 12) were obtained from heavy weight carcasses (mean = 407.8 kg), assigned to one of two aging treatments (dry or wet) and aged for 35 days at a commercial aging facility. Cutting tests were performed at the end of the aging period to determine retail yields. Subprimals were fabricated using the Beef Alternative Merchandising cutting styles, isolating four specific muscles: *M. spinalis thoracis, M. longissimus thoracis, M. gluteobiceps,* and *M. gluteus medius*. Retail cutting tests showed wet-aged subprimals had higher ($P < 0.0001$) total saleable yield percentages with decreased cooler shrink and gross cut loss percentages. This resulted in wet-aged ribeye rolls and top sirloin butts yielding 1.5 times and 1.3 times more saleable product than dry-aged counterparts, respectively. In order to determine palatability characteristics, consumer sensory evaluations and trained panel evaluations were preformed. Palatability related to aging and muscle type resulted in significant differences. From a consumer standpoint, aging treatment influenced OLIKE, FLAV, FLEVEL, and BEEFLIKE but only through the interaction of aging treatment × muscle. Clearly, consumers rated the wet-aged, *M. spinalis thoracis* highest in each of the previously stated attributes. Aging also affected JUIC, whereas muscle type had a significant ($P < 0.0001$) effect on FLVBF, TEND, LEVTEND, JUIC, and LEVJUIC. As far as trained sensory attributes were concerned, a more concrete flavor profile of aged beef was obtained. In addition, dry-aged steaks had greater ($P < 0.0001$) cooking yield percentages when compared to wet-aged steaks.

DEDICATION

This thesis is dedicated to my family for their tremendous dedication and support. I would not be who I am today without them. Thank you to John, Dana, Kari, and Emily. God has truly blessed me beyond measure to have all of you in my life.

ACKNOWLEDGEMENTS

I thank my committee for their guidance and support. Drs. Savell and Harris have worked diligently to develop my research abilities and have taken the time to further encourage me professionally while serving as Co-Chairs of my committee. Dr. Griffin was extremely helpful in the planning and execution of this thesis project, in addition to his mentorship during my graduate and undergraduate studies. My time at Texas A&M has been successful due to the role each of you have played in my life. Thank you for always supporting me and pushing me to be a better person.

I also thank Drs. Miller and Kerth for their much-appreciated help in multiple areas of this project. Your expertise in sensory and flavor was exceptionally helpful throughout my study.

My gratitude also is extended to my friends, colleagues, faculty, and staff for making my time at Texas A&M University a great experience. I also thank Ray Riley for his support and allowing me the use of Rosenthal. Thank you to Dr. Cross for his professional development and guidance. I appreciate the assistance I received from my fellow graduate students during this process: Leslie Frenzel, Gatlan Gray, Adria Grayson, Haley Grimes, Kaitlyn Grimshaw, Ashley Haneklaus, Meagan Igo, Cody Labus, Russell McKeith, Lindsey Mehall, Melanie Moore, Kayla Nelson, and Carson Ulbrich. I am also thankful for the meat science student workers: Jenny Bohac, Nathan Labus, Julie Lockhart, and Julianne Riley.

Thank you to industry supporters who helped in the execution of this project. First, to Lonestar Food Service for their overwhelming assistance during the aging of the product, especially Franklin Hall and Tony Sousa. Also, I appreciate Ruffino Meats for their aid in transportation of the product.

Finally, thanks to my mother and father for their encouragement and to my sisters for their love and support.

TABLE OF CONTENTS

Page

LIST OF TABLES

TABLE Page

1. INTRODUCTION

A challenge facing the meat industry today is increasing uniformity of portion size in order to combat the continued increase in the average carcass weight by approximately 1 kg per year (Boleman et al., 1998; Garcia et al., 2008; Lorenzen et al., 1993; McKenna et al., 2002; Moore et al., 2012). As a potential solution to this problem, West et al. (2011) used the Beef Alternative Merchandising cutting styles outlined in the SIMPLYBEEF Guide produced by the National Cattlemen's Beef Association (National Cattlemen's Beef Association, 2009a, 2009b). This study showed that despite increased labor costs and yield losses, these methods do create a more uniform, better-portioned product. Currently, the literature lacks published research evaluating whether these cutting styles can be functional in a dry-aging environment.

The two most common forms of aging are dry and wet aging. Smith et al. (2008) described dry aging as unpackaged meat aged at controlled temperatures and humidity. On the contrary, wet aging refers to storing meat in a vacuum-sealed package at refrigeration temperatures. Since the introduction of vacuum packaged boxed beef, wet aging has continued to be the normal industry aging system due to its increased ease and flexibility of storage, while still producing more tender, more consistent products. There seems to be an increase in number of establishments preparing dry-aged product for upscale retail and foodservice markets, despite the additional requirements of a greater amount of space and proper facilities to control temperature, relative humidity, and air-flow for dry aging.

Despite increased research in this area within recent years, there is still a need to understand the complex flavor profile of dry-aged beef. By utilizing the Beef Alternative Merchandising cutting styles, individual muscles can be isolated in order to provide a unique perspective of how aging influences beef.

The objectives of this study were to determine the influence aging method has on the saleable yield of cuts generated using the innovative cutting styles, to determine consumer acceptance and (or) preference of beef steaks from four different muscles based on aging style, and to better determine the unique flavor profiles specific to dry-aged and wet-aged steaks. By providing this knowledge, all segments of the industry will gain an added understanding of the flavor profiles specific to aged beef and then use this information to better promote beef in the marketplace.

2. REVIEW OF LITERATURE

2.1. Aging

Meat palatability relates to how the meat tastes and is defined in terms of juiciness, tenderness, and flavor (Miller, 2004). Juiciness is described as the perceived juices during mastication. Tenderness is the ease of bite and breakdown during chewing. Flavor results from an accumulation of olfactory senses – aromatics perceived, the basic tastes as perceived by the tongue, feel factors in the mouth during consumption, and perceived aftertastes post consumption (Miller, 2004). Of the three palatability indicators, tenderness contributes most to consumers' perception of taste (Koohmaraie, Seideman, Schollmeyer, Dutson, & Babiker, 1988; Lorenzen et al., 1999; Neely et al., 1998, 1999; Savell et al., 1999). Postmortem aging promotes palatability through increased tenderness (Bidner, Montgomery, Bagley, & McMillin, 1985; Davis, Huffman, & Cordray, 1975; Oreskovich, McKeith, Carr, Novakofski, & Bechtel, 1988; Smith, Culp, & Carpenter, 1978).

Tenderness is influenced by many factors including postmortem proteolysis, connective tissue quantity and strength, contractile state of the muscle, intramuscular fat, and ionic strength. Postmortem proteolysis is simply a continuation of naturally occurring enzymes after the carcass has gone into rigor. The Z-disk is clearly altered by such proteases (Goll et al., 1983), though significant degradation takes 3 to 4 days postmortem (Taylor, Geesink, Thompson, Koohmaraie, & Goll, 1995). Furthermore, Koohmaraie, Babiker, Merkel, and Dutson (1988) identified the protease responsible to be calpain, an enzyme naturally present in mammalian cells in two different forms – μ-calpain and m-calpain. In living cells, calpains function during fusion and differentiation of the cell, in membrane degradation, and in cytoskeletal remodeling. In addition, they concluded these calcium-dependent enzymes are sufficient to reproduce the changes in the myofibrils associated with postmortem storage as μ-calpain retained 24-28% of its activity at pH 5.5 to 5.8 and 5 °C in postmortem muscle. Despite previous thoughts that actin and myosin are not degraded postmortem, Goll, Taylor, and Thompson (1995) showed that through the process of ADP hydrolysis, there was some binding with these proteins, causing the "permanent" actin-myosin cross-bridge to weaken. This is consistent with previous research showing solubilization of proteins from the thick and thin filaments due to ionic strength changes postmortem (Wu & Smith, 1987).

Tenderness is also improved by collagen degradation. It (Nishimura, Hattori, & Takahashi, 1995; Nishimura, Hattori, & Takahashi, 1996) evaluated intramuscular connective tissue of a Japanese black steer and collected scanning electron micrographs both immediately postmortem and after various aging times. After 28 days, there was a significant loosening of the endomysium and perimysial sheets disintegrated and separated into collagen fibers of 4-8 μm in diameter.

2.2. Procedures for aging

The act of dry-aging is more of an "art" rather than a "science," allowing for a range in procedure parameters based on the individual goals of the aging facility. Lautenschläger (2012) described dry-aging as "enjoying a renaissance," but this pleasure comes at the expense of the highly specialized process. Generally, days of aging, storage temperature, relative humidity, and airflow are the parameters of interest for the dry-aging process.

Savell (2008a) discussed the array of aging days used both in practice and in literature, ranging from 7 to 35 days. Savell also concluded that the limited scientific information available makes it impossible to support a minimum recommended period of dry aging. On the contrary, a recent article by Perry (2012) claimed that 50 to 80 days is necessary for maximum flavor development, despite not presenting any data to support such claims. Smith et al. (2008) found fewer differences in consumer sensory evaluations across aging periods, 14, 21, 28, and 35 days, but did see significant decreases in Warner-Bratzler shear force values. Specifically, there was a 17% decrease in reduction in shear force from 14 to 35 days. Campbell, Hunt, Levis, and Chambers (2001) found decreased shear force for steaks aged to 21 days, with little other improvements past 14 days of age. Laster et al. (2008) saw minimal differences in palatability or saleable yield over aging periods (14 d, 21 d, 28 d, or 35 d). Minks and Stringer (1972) showed a clear increase in sensory attributes and decrease in shear force after 15 days, but did not age subprimals longer.

Storage temperature during the aging process tends to center around 1°C, ensuring the environment is not below freezing (-2 to -3ºC), ceasing the enzymatic processes involved in aging. There is a variety of dry-aging temperatures in the literature: Ahnström, Seyfert, Hunt, and Johnson (2006) held product at 2.5 ºC and 2.6 ºC; Campbell et al. (2001) at 2.0 ºC; Lautenschläger (2012) at 1.0 ºC; Laster et al. (2008) at -0.6 ºC; Parrish, Boles, Rust, and Olson (1991) at 0 ºC to 1 ºC; Sitz, Calkins, Feuz, Umberger, and Eskridge (2006) at 1.0 ºC; Smith et al. (2008) at 1.0 ºC; Oreskovich et al.

(1988) at 2.0 ºC; Warren and Kastner (1992) 3.1 to 3.6 ºC; and Perry (2012) recommends -0.5 ºC to 1.0 ºC.

Relative humidity is arguably the most variant of dry-aging parameters. As described by Savell (2008a), this parameter is important because if too high, spoilage bacteria can grow and result in off-odors and possibly off-flavors; yet if too low, excess product shrinkage will occur. Savell also stated that there was yet to be any published studies comparing this parameter, noting there was a plethora of relative humidity parameters in the literature. Campbell et al. (2001) dry-aged in a cooler with a relative humidity of 75% and Laster et al. (2008) used a relative humidity of 78%. Parrish et al. (1991) stored dry-aged product at a range of 80-85%, which is agreeable to the range suggested by Perry (2012). Smith et al. (2008) used a cooler with a relative humidity 83 ± 11%, whereas Ahnström et al. (2006) used a relative humidity of 87 ± 2.6%. The highest relative humidity for dry aging was reported as 90% by Lautenschläger (2012).

Airflow in dry aging rooms has not been well documented in the literature, but is important in practice. Special wire racks, perforated shelves, trees, or hooks are used to hold products for dry aging so that all surfaces are exposed to the air for uniform drying and minimize spoilage (Savell, 2008a). Fans are generally used to better circulate the air around the product. Often, ultraviolet lights are used to retard mold growth (Perry, 2012).

2.3. Increasing uniformity of portion size

A challenge facing the meat industry today is a lack of uniform portion size. Findings from the National Beef Quality Audits (Boleman et al., 1998; Garcia et al., 2008; Lorenzen et al., 1993; McKenna et al., 2002; Moore et al., 2012) have shown a continued increase in the average carcass weight by approximately 1 kg per year. Current beef pricing strategies provide producers incentives for producing heavier cattle, often resulting in cattle with larger muscle size. Along with this increase in carcass weight, consumers are left with extreme variation in both retail and foodservice cut size (Bass, Scanga, Chapman, Smith, & Belk, 2009; Dunn, Williams, Tatum, Bertrand, & Pringle, 2000; Leick, Behrends, Schmidt, & Schilling, 2011; Sweeter, Wulf, & Maddock, 2005).

Previous research has focused on using ribeye (*M. longissimus thoracis*) area at the 12th and 13th rib interface as a means of segregating carcasses into more conforming groups. Beef carcasses with ribeye less than 71.0 cm^2 or greater than 103.2 cm^2 may be considered nonconforming (Savell, 2008b). Furthermore, Dunn et al. (2000) evaluated beef strips of varying portions based on ribeye and found 77.4 to 99.6 cm^2 to be the most optimal in tenderness and cooking time. However, Bass et al. (2009) demonstrated that portion size for many cuts was still acceptable, despite the fact that carcass ribeye size was outside the commercially acceptable range. From a retail standpoint, Sweeter et al. (2005) found that there was no optimum for ribeye for beef consumers, despite a trend toward greater consumer demand for steaks originating from carcasses with larger ribeye over smaller ones. This was expressed by product time in retail case, as well as in a mock auction setting. Similar results were found by Leick et al. (2011), who showed consumers selecting ribeye steaks from carcasses with a ribeye within the largest range, 101.94-109.03 cm^2.

Two of the goals highlighted in the Beef Non-Conformity Research Needs outlined by Savell (2008b) were to establish an understanding of cut dimension as it relates to use, and to utilize alternative cutting styles to increase value from heavier weight carcasses. As a response to these goals, West et al. (2011) used the Beef Alternative Merchandising cutting styles outlined in the SIMPLYBEEF Guide produced by the National Cattlemen's Beef Association (National Cattlemen's Beef Association, 2009a, 2009b) as a way to combat this trend toward heavier cuts. West et al. (2011) found that while using these innovative cutting styles might create more uniform cuts, it comes at the expense of decreased saleable yield and increased labor requirements, which would result in higher retail price. This significant increase in price was calculated as 11.6% for top sirloin butts, 26.9% for ribeye, and 2.6% for strip loin in this study.

3. MATERIALS AND METHODS

3.1. Product selection

Beef carcasses (*n* = 12) grading U.S. Department of Agriculture (1997) Choice with carcass weights averaging 407.8 kg were identified at a major beef processor (carcass characteristics are shown in Table 1). Both sides from each were fabricated, and Institutional Meat Purchase Specifications (NAMP, 2010; U.S. Department of Agriculture, 2010) Beef Loin, Top Sirloin Butt, Boneless (IMPS 184) and Beef Rib, Ribeye, Lip-On, Boneless (IMPS 112A) subprimals were obtained, labeled with carcass number and side, vacuum packaged, and boxed. Subprimals then were shipped commercially via a refrigerated truck to a commercial aging facility in Austin, TX.

3.2. Aging treatments

Subprimals were separated into one of two treatments, dry or wet aging. All odd numbered, left subprimals were assigned to dry-aging and all odd numbered, right subprimals were assigned to wet-aging. Similarly, all even numbered, left subprimals were prescribed to wet-aging with all even numbered, right subprimals were allotted to wet-aging. Each side (right and left) was represented equally among aging treatments. Vacuum packaged subprimals designated for wet aging were placed under refrigeration temperatures (3.0±0.7 ºC). Those assigned to the dry-aging group were weighed initially in the bag, and reweighed after the bag was removed. Vacuum packaged bags were rinsed with water and dried before weighing to calculate purge loss. The subprimals identified for dry aging were placed in storage on a perforated, plastic rack alongside similar racks filled with beef subprimals being dry-aged for sale by the commercial operation cooperating in this study. Temperature and relative humidity of the cooler (4.0±1.1 ºC; 98.1% Rh) were monitored using a continuous data logging device and probe (Model TM325; Dickson Data, Addison, IL). Conditions for dry-aging were the parameters employed by the plant to dry-age all of their dry-aged beef. Furthermore, within the dry-aging cooler, fans were used for better air circulation along with UV lights to inhibit mold growth. During the aging process, product was flipped every 3 to 5 days in accordance with the facilities traditional practices. After 35 days of aging, subprimals were shipped under refrigeration to the Rosenthal Meat Science and Technology Center at Texas A&M University for fabrication into retail cuts.

3.3. Retail cutting tests

A retail market environment was simulated in a refrigerated cutting room at the Rosenthal Meat Science and Technology Center for the purpose of conducting retail yield tests. All subprimals were cut in accordance with the Beef Alternative Merchandising (BAM) cutting styles outlined in the SIMPLYBEEF Guide produced by the National Cattlemen's Beef Association, following the procedures used by West et al. (2011). An experienced meat cutter with extensive knowledge and experience with the BAM cutting styles fabricated the subprimals.

Retail cutting tests consist of three phases: opening (removal of subprimal from the vacuum package bag), precut trimming (any trimming necessary before retail cuts can be made, i.e., removal of dried surfaces, removal of tails on ribeye rolls etc.), and cutting (producing tray-ready retail cuts, and removal of external and seam fat as deemed necessary on certain cuts). After each cutting test, trained Texas A&M personnel recorded weights of all fabricated components: steaks, lean trim, stew meat, fat trim, bone, and waste. Weights were summed to ensure that at least 99% of the initial subprimal weight was recovered. Post fabrication, each steak was vacuum packaged individually, labeled, and frozen at -23 °C for subsequent cooking and dissection.

3.4. Wet-aged cutting tests

3.4.1. Beef Rib, Ribeye Roll, Lip-On (IMPS #112A)

Vacuum packaged ribs were weighed in the bag (in bag weight), then taken out of the bag and reweighed (out of bag weight). In order for a purge loss value to be calculated, vacuum package bags were rinsed with water, dried, and weighed. The tail was first removed from the ribeye at the natural seam. Afterwards, the *M. spinalis thoracis* was removed following the natural seam, cleaned of heavy connective tissue and intermuscular fat, and then cut across the grain into 3.81 cm-wide URMIS 1254 – Beef Ribeye Cap Steak Boneless. The *M. complexus* and intermuscular fat were removed from the remainder of the ribeye. Starting on the anterior end of the remaining portion, 3.81 cm thick URMIS 1253 – Beef Ribeye Filet Boneless were removed until steaks approached the size that would necessitate splitting for a more consistent portion weight. The remaining portion was split into two logs, each then cut into 3.81 cm-wide filets. Any residual pieces were weighed as stew meat.

3.4.2. Beef Loin, Top Sirloin Butt, Boneless (IMPS #184)

Vacuum packaged sirloins were weighed in the bag (in bag weight), then taken out of the bag and reweighed (out of bag weight). For a purge loss value to be calculated, vacuum packaged bags were rinsed, dried, and weighed. Processing began by removing the *M. gluteobiceps* (IMPS 184D – Beef Loin, Top Sirloin, Cap (IM)) and cutting this muscle into 2.54 cm-thick steaks across the grain and trimming to have no more than 0.3 cm external fat to create URMIS 1421 – Beef Loin Top Sirloin Cap Steak Boneless (BAM). The *M. gluteus accesorius* and the *M. gluteus profundus* was removed from the remaining sirloin section and used as lean trimmings. The remaining *M. gluteus medius* was divided into thirds and each was cut into 3.81 cm-thick URMIS 1323 – Beef Loin Top Sirloin Filet Boneless (BAM).

3.5. Dry-aged cutting tests

3.5.1. Beef Rib, Ribeye Roll, Lip-On, Boneless (IMPS #112A)

Dry-aged ribeyes were weighed prior to cutting to determine an initial cut weight. Exterior surfaces were faced to remove the dried out surface tissue sometimes referred to as the "crust" and was weighed as such. Steaks were cut in the same manner as the wet-aged steaks.

3.5.2. Beef Loin, Top Sirloin Butt, Boneless (similar to IMPS #184)

Dry-aged sirloins were weighed prior to cutting to determine an initial cut weight. Exterior surfaces were trimmed of any dried surface tissue, recorded as "crust" and external fat was trimmed to 0.3 cm, recorded as fat trim. Steaks were cut in the same manner as the wet-aged steaks.

3.6. Consumer panels

Consumer panelists (*n*=107) were recruited from the Bryan/College Station area using an existing consumer database. Upon arrival at the sensory facility, panelists were asked to fill out a demographic survey (Table 2). Steaks selected for sensory evaluation were removed from the freezer 48 hours prior to cooking and allowed to thaw in the cooler (~2 °C). Steaks were cooked on indoor electric grills (Hamilton Beach Indoor/Outdoor Grill, Hamilton Beach/Proctor Silex, Inc., Southern Pines, NC) and temperature was continuously monitored by the use of Omega trendicators (Omega Engineering, Inc., Stamford, CT) fitted with type-T thermocouples. Steaks were cooked to an internal temperature of 35 °C, flipped, and cooked to a final temperature of 70 °C. Two 1.27 cm cube samples from steaks representing individual subprimals were served randomly to panelists while seated in individual sensory booths under red lights.

Panelists were asked to evaluate eight samples using 9-point scales for overall like (**OLIKE**)(1=dislike extremely; 9=like extremely), flavor like (**FLAV**)(1=dislike extremely; 9=like extremely), level of flavor (**FLEVEL**)(1=extremely bland or no flavor; 9=extremely flavorful or intense), beef flavor like (**BEEFLIKE**)(1=dislike extremely; 9=like extremely), level of beef flavor (**FLVBF**)(1=extremely bland or no flavor; 9=extremely flavorful or intense), tenderness like (**TEND**)(1=dislike extremely; 9=like extremely), level of tenderness (**LEVTEND**)(1=extremely tough; 9=extremely tender), juiciness like (**JUIC**)(1= dislike extremely; 9=like extremely), and level of juiciness

(**LEVJUIC**)(1=extremely dry; 9=extremely juicy). Consumers were given a monetary award of $20 for their participation in this study.

3.7. Trained sensory panel

A five-member expert meat and flavor descriptive attribute panel (trained as defined by AMSA, 1995, and Meilgaard, Civille, & Carr, 2007) was used. Panelists were familiarized for 2 days with samples that would be used in the study. They were seated in individual booths equipped with red lights, and received cooked, unseasoned, wet-aged beef top loin steak cubes as warm-up samples. Analyses were performed over 8 sensory days.

Cooked sections were cut into 1 cm^3 cubes, placed in plastic weigh boats, and served immediately. Each day, panelists evaluated 12 samples, served 5 min apart, during 2 sessions (7 samples per session) with a 15 min break between sessions. Panelists cleansed their palate between samples with double-distilled deionized water and whole milk ricotta cheese.

Trained panelists evaluated the beef flavor identities: brown/roasted, serumy/bloody, fat-like, metallic, liver-like, unami, overall sweet, sweet, sour, salty, bitter, sour aromatics, green-haylike; aromatics: barnyard, animal hair, burnt, heated oil, chemical, apricot, asparagus, cumin, floral, beet, chocolate, green-grass, musty-earthy/humus, medicinal, petroleum like, smokey charcoal, smokey wood, spoiled-putrid, dairy, buttery, cooked milk, sour milk/dairy, refrigerator stale, warmed-over, soapy, painty, fishy, and cardboard; and aftertastes: barnyard, bitter, musty-earthy, sour, and metallic using a 16-point scale (0 = none and 15 = extremely intense).

The remaining edible portion from each steak assigned for trained panel was saved in a glass dish and immediately placed in a -80 ºC freezer for further analysis.

3.8. Statistical analysis

The effects of aging treatment (dry and wet), muscle type (*M. longissimus thoracis, M. spinalis thoracis, M. gluteus medius,* and *M. gluteobiceps*), and aging treatment × muscle type were analyzed by analysis of variance programs using JMP® Software (JMP®, Version 9.0.0, SAS Institute Inc., Cary, NC, 1989-2010). Interactions that were not significant were removed from the model. The p-diff option at $P < 0.05$ was used to separate means when significant differences occurred. Box-Cox transformation was used to ensure normal distribution for analysis of consumer data.

4. RESULTS AND DISCUSSION

4.1. Retail cutting tests

The influence aging treatment had on retail yield and by-product percentage of ribeye rolls is shown in Table 3. Wet-aged ribeye rolls produced greater percentages of ribeye filets ($P < 0.0001$), ribeye cap steaks ($P < 0.0001$), *M. complexus* steaks ($P < 0.05$), and lean trimmings ($P < 0.0001$). Wet-aged ribeye rolls also yielded greater percentages of fat ($P < 0.0001$), purge ($P = 0.0007$), and connective tissue and bone ($P = 0.0022$). Alternatively, dry-aged ribeye rolls produced greater percentages ($P < 0.0001$) of crust and cooler shrink, which is to be expected due to the increased moisture loss in dry-aged products. Wet-aged ribeye rolls had greater ($P < 0.0001$) total saleable yields than the dry-aged ribeye rolls, yielding over 1.5 times more saleable product. This mirrors the Laster et al. (2008) study, which showed wet-aged ribeye rolls for all four aging periods to have significantly greater total saleable yield than their dry-aged counterparts.

Table 4 presents aging treatment and its effect on retail yield and by-product percentage of top sirloin butts. Percentages produced were greater for wet-aged top sirloin filets ($P = 0.0001$), top sirloin cap steaks ($P = 0.0059$), and lean trimmings ($P < 0.0001$) when compared to dry-aged top sirloin butts. Interestingly, percentage stew meat was similar ($P = 0.9918$) for both wet and dry-aged top sirloin butts. Most logically, this can be attributed to the fact that the origin of stew meat would be from the more interior regions of the top sirloin butt, making it less prone to moisture loss. As was found in the ribeye rolls, wet-aged top sirloin butts yielded greater percentages of fat ($P < 0.0001$), purge ($P < 0.0001$), and connective tissue and bone ($P < 0.0001$). Similarly, dry-aged top sirloin butts produced greater ($P < 0.0001$) percentages of both crust and cooler shrink. Overall, wet-aged top sirloin butts yielded greater ($P < 0.0001$) percentages of total saleable yield, resulting in approximately 1.3 times more product per top sirloin butt. This result is similar to findings found by Smith et al. (2007) and Laster et al. (2008), as well as the ribeye roll yields within this study.

The number of steaks resulting from fabrication of ribeye rolls and top sirloin butts is shown in Table 5. Wet-aged subprimals generated 1.1 more ($P < 0.0001$) ribeye cap steaks and 1.2 more ($P = 0.0006$) top sirloin filets were generated when compared to dry-aged product produced during fabrication. There was no ($P > 0.05$) difference in the number of ribeye filets or top sirloin cap steaks created between wet-aged and dry-aged subprimals.

No differences ($P > 0.05$) were found in steak measurements within aging treatments or muscle; however, there was an interaction ($P < 0.0001$) between individual steak measurements between aging treatment and muscle (Table 6). Wet-aged, *M. gluteobiceps* yielded the longest ($P < 0.0001$) steaks followed by dry-aged steaks from the same muscle group. These steaks were followed by wet-aged, *M. gluteus medius*, which were longer than the wet-aged, *M. longissimus thoracis.* The widest steaks were the wet-aged, *M. spinalis thoracis* ($P < 0.0001$) followed by the dry-aged, *M. spinalis thoracis* ($P < 0.0001$).

Table 7 displays steak portion weights by aging treatment and muscle type. The individual portion weights of steaks fabricated from wet-aged subprimals were heavier ($P < 0.0001$) than those created from dry-aged subprimals. Furthermore, steaks originating from the *M. longissimus thoracis* were heavier ($P < 0.0001$) than other muscle types, followed by steaks from the *M. gluteus medius*. There was not a significant difference in individual portion weights of steaks from the *M. spinalis thoracis* and the *M. gluteobiceps*. There was no interaction ($P > 0.05$) between aging treatment and muscle where portion weight was concerned.

4.2. Consumer panels

Table 2 portrays the demographic information for the sensory panelists involved in this study. The largest majority of participants were between the ages of 22-29 (51.4%), making less than US$20,000 (44.9%), and worked part time (37.4%).

Table 8 presents least squares means for cooking temperatures, cooking times, and cooking yields from consumer evaluations of beef steaks. There were no significant ($P > 0.05$) differences for internal temperature endpoint. Aging treatment significantly affected cooking yield. Dry-aged steaks had greater ($P < 0.0001$) cooking yield percentages when compared to wet-aged steaks. Laster et al. (2008) showed similar results in cook yield when related to top sirloin steaks. The *M. gluteobiceps* had significantly ($P < 0.0001$) shorter cook times when compared to the other muscles. Though not significantly different, dry-aged steaks took longer to cook than wet-aged steaks, similar to the ribeye steaks in the Laster et al. (2008) study.

Aging period had a significant effect on JUIC (Table 9). As found by Smith et al. (2007), wet-aged steaks were perceived as more favorable from a juiciness standpoint ($P = 0.0383$).

The effects of muscle type on palatability characteristics of beef steaks are presented in Table 9. Muscle type had an effect ($P < 0.0001$) on FLVBF, TEND, LEVTEND, JUIC, and LEVJUIC. The *M. spinalis thoracis* was rated higher than other muscles in respect to each of the previously stated attributes. In addition, the *M. gluteus medius* had the lowest ($P < 0.0001$) ratings for TEND, LEVTEND, JUIC, and LEVJUIC.

Four significant interactions between aging treatment × muscle were found for OLIKE, FLAV, FLEVEL, and BEEFLIKE (Table 10). Clearly, consumers rated the wet-aged, *M. spinalis thoracis* highest in each of the previously stated attributes. Within each muscle type, wet-aged steaks were numerically higher for each attribute when compared to dry-aged steaks. Generally speaking, steaks generated from the ribeye had higher ratings than did steaks fabricated from the top sirloin butt, whether wet or dry.

4.3. Trained panels

Table 11 presents least squares means for cooking temperatures, cooking times, and cooking yields from trained evaluations of beef steaks. Though not significantly different, dry-aged steaks tended to require longer cook times but resulted in greater cook yield. This was consistent with the results of the cooking data for the consumer steaks from this study. No differences ($P > 0.05$) for internal temperature endpoint were found. There were significant ($P < 0.0001$) differences in the amount of time required for cooking within muscles. The more exterior muscles, the *M. spinalis thoracis* and the *M. gluteobiceps*, required less cooking time, which can most likely be attributed to their smaller cut size and increased surface-to-volume ratio.

Aging period had a significant effect on metallic flavor (Table 12). Dry-aged steaks were higher ($P = 0.0251$) in metallic flavor when compared to their wet-aged counterparts.

The effects of muscle type on palatability characteristics of beef steaks from a trained panelist standpoint are presented in Table 12. There was a significant difference in both fat ($P < 0.0001$) and metallic ($P < 0.0001$) flavors between muscles. Fat-like aromatics followed the trend to be greater in fattier cuts, or those cuts more exposed to the external surface. Furthermore, cuts fabricated from the ribeye roll showed to be less metallic than those from the top sirloin butt. This was to be expected because the sirloin is generally associated with metallic aromatics (Carmack, Kastner, Dikeman, Schwenke, & Garcia Zepeda, 1995)

Significant interactions between aging treatment × muscle were associated with attributes of beef flavor ($P = 0.0372$), brown roasted ($P = 0.0358$), bloody/serumy ($P = 0.0310$), musty ($P = 0.0052$), putrid ($P = 0.0007$), and warmed over flavor ($P = 0.0043$). Differences in beef flavor seemed to trend towards being higher for wet-aged steaks versus those that were dry-aged in addition to being higher in the more internal muscles of the *M. longissimus thoracis* and the *M. gluteus medius*. Similarly, brown/roasted flavor was generally higher with the same trend. Bloody/serumy attributes were highest for the wet-aged *M. spinalis thoracis* and *M. gluteus medius*. Generally speaking, bloody/serumy trended to be lower for wet-aged steaks than dry-aged steaks, which opposes findings from Warren and Kastner (1992). Musty and putrid flavors both were higher for dry-aged product and muscles closer to the exterior surface of the subprimal. These surfaces would be more physically exposed to drying and mold growth contact in dry aging. Furthermore, in both aging styles, the more exterior muscles would be closer to the larger fat depots within the subprimals used in this study. Warmed over flavor, although significantly different, lacked an evidenced trend to explain differences based on aging and muscle type. Perhaps further research could explain these differences.

Those attributes that were eliminated from the model include: beef flavor identities of liver-like, unami, overall sweet, sweet, sour, salty, bitter, and green-haylike; the aromatics of sour, barnyard, animal hair, burnt, heated oil, chemical, apricot, asparagus, cumin, floral, beet, chocolate, green-grass, musty-earthy/humus, medicinal, petroleum like, smokey charcoal, smokey wood, dairy, buttery, cooked milk, sour milk/dairy, refrigerator stale, soapy, painty, fishy, and cardboard; and aftertastes or barnyard, bitter, musty-earthy, sour, and metallic. All of these attributes lacked differences ($P > 0.05$), and therefore were not of use in this study.

5. CONCLUSIONS

Retail cutting tests showed that dry-aged subprimals experienced lower total saleable yield then wet-aged subprimals. Furthermore, by utilizing the Beef Alternative Merchandising cutting styles, these losses were further increased from normal aging practices. The overall decreased saleable yield and longer fabrication times would ultimately lead to a higher priced product. The question remains if this increase in price would be accepted at the retail or foodservice level.

Palatability related to aging and muscle type resulted in definite differences. From a consumer standpoint, aging treatment influenced OLIKE, FLAV, FLEVEL, and BEEFLIKE but only through the interaction of aging treatment × muscle. Aging also affected JUIC, whereas muscle influenced FLVBF, TEND, LEVTEND, JUIC, and LEVJUIC. As far as trained sensory attributes were concerned, a more concrete flavor profile of aged beef was obtained.

REFERENCES

Ahnström, M. L., Seyfert, M., Hunt, M. C., & Johnson, D. E. (2006). Dry aging of beef in a bag highly permeable to water vapour. *Meat Science*, *73*(4), 674-679.

AMSA. (1995). Research guidelines for cookery, sensory evaluation and instrumental tenderness measurements of fresh meat. Chicago, IL: National Live Stock and Meat Board.

Bass, P. D., Scanga, J. A., Chapman, P. L., Smith, G. C., & Belk, K. E. (2009). Associations between portion size acceptability of beef cuts and ribeye area of beef carcasses. *Journal of Animal Science*, *87*(9), 2935-2942.

Bidner, T. D., Montgomery, R. E., Bagley, C. P., & McMillin, K. W. (1985). Influence of electrical stimulation, blade tenderization and postmortem vacuum aging upon the acceptability of beef finished on forage or grain. *Journal of Animal Science*, *61*, 584-589.

Boleman, S. L., Boleman, S. J., Morgan, W. W., Hale, D. S., Griffin, D. B., Savell, J. W., Ames, R. P., Smith, M. T., Tatum, J. D., Field, T. G., Smith, G. C., Gardner, B. A., Morgan, J. B., Northcutt, S. L., Dolezal, H. G., Gill, D. R., & Ray, F. K. (1998). National Beef Quality Audit-1995: Survey of producer-related defects and carcass quality and quantity attributes. *Journal of Animal Science*, *76*(1), 96-103.

Campbell, R. E., Hunt, M. C., Levis, P., & Chambers, E., IV. (2001). Dry-aging effects on palatability of beef longissimus muscle. *Journal of Food Science*, *66*(2), 196-199.

Carmack, C. F., Kastner, C. L., Dikeman, M. E., Schwenke, J. R., & Garcia Zepeda, C. M. (1995). Sensory evaluation of beef-flavor-intensity, tenderness, and juiciness among major muscles. *Meat Science*, *39*(1), 143-147.

Davis, K. A., Huffman, D. L., & Cordray, J. C. (1975). Effect of mechanical tenderization, aging, and pressing on beef quality. *Journal of Food Science*, *40*(6), 1222-1224.

Dunn, J. L., Williams, S. E., Tatum, J. D., Bertrand, J. K., & Pringle, T. D. (2000). Identification of optimal ranges in ribeye area for portion cutting of beef steaks. *Journal of Animal Science*, *78*(4), 966-975.

Garcia, L. G., Nicholson, K. L., Hoffman, T. W., Lawrence, T. E., Hale, D. S., Griffin, D. B., Savell, J. W., VanOverbeke, D. L., Morgan, J. B., Belk, K. E., Field, T. G., Scanga, J. A., Tatum, J. D., & Smith, G. C. (2008). National Beef Quality Audit-2005: Survey of targeted cattle and carcass characteristics related to quality, quantity, and value of fed steers and heifers. *Journal of Animal Science*, *86*(12), 3533-3543.

Goll, D. E., Otsuka, Y., Nagainis, P. A., Shannon, J. D., Sathe, S. K., & Muguruma, M. (1983). Role of muscle proteinases in maintenance of muscle integrity and mass. *Journal of Food Biochemistry*, *7*(3), 137-177.

Goll, D. E., Taylor, R. G., & Thompson, V. F. (1995). Does proteolysis cause all the postmortem tenderization or are changes in actin/myosin interaction involved? In *Proceedings of the Proc. 41st International Congress of Meat Science and Technology* (537–544), San Antonio, TX.

Koohmaraie, M., Babiker, A. S., Merkel, R. A., & Dutson, T. R. (1988). Role of Ca^{++}-dependent proteases and lysosomal enyzmes in postmortem changes in bovine skeletal muscle. *Journal of Food Science*, *53*(5), 1253-1257.

Koohmaraie, M., Seideman, S. C., Schollmeyer, J. E., Dutson, T. R., & Babiker, A. S. (1988). Factors associated with the tenderness of three bovine muscles. *Journal of Food Science*, *53*(2), 407-410.

Laster, M. A., Smith, R. D., Nicholson, K. L., Nicholson, J. D. W., Miller, R. K., Griffin, D. B., Harris, K. B., & Savell, J. W. (2008). Dry versus wet aging of beef: Retail cutting yields and consumer sensory attribute evaluations of steaks from ribeyes, strip loins, and top sirloins from two quality grade groups. *Meat Science*, *80*(3), 795-804.

Lautenschläger, R. (2012). Latest trends in beef maturation – Dry-aged versus wet-aged beef. In *Proceedings of the 58th International Congress of Meat Science and Technology*, 12-17 August 2012, Montréal, Canada.

Leick, C. M., Behrends, J. M., Schmidt, T. B., & Schilling, M. W. (2011). Consumer selection of constant-weight ribeye, top loin, and sirloin steaks. *Meat Science*, *87*(1), 66-72.

Lorenzen, C. L., Hale, D. S., Griffin, D. B., Savell, J. W., Belk, K. E., Frederick, T. L., Miller, M. F., Montgomery, T. H., & Smith, G. C. (1993). National Beef Quality Audit: Survey of producer-related defects and carcass quality and quantity attributes. *Journal of Animal Science*, *71*(6), 1495-1502.

Lorenzen, C. L., Neely, T. R., Miller, R. K., Tatum, J. D., Wise, J. W., Taylor, J. F., Buyck, M. J., Reagan, J. O., & Savell, J. W. (1999). Beef Customer Satisfaction:

Cooking method and degree of doneness effects on the top loin steak. *Journal of Animal Science*, *77*(3), 637-644.

McKenna, D. R., Roeber, D. L., Bates, P. K., Schmidt, T. B., Hale, D. S., Griffin, D. B., Savell, J. W., Brooks, J. C., Morgan, J. B., Montgomery, T. H., Belk, K. E., & Smith, G. C. (2002). National Beef Quality Audit-2000: Survey of targeted cattle and carcass characteristics related to quality, quantity, and value of fed steers and heifers. *Journal of Animal Science*, *80*(5), 1212-1222.

Meilgaard, M. C., Civille, G. V., & Carr, B. T. (2007). *Sensory evaluation techniques* (4th ed.). Boca Rotan, FL: CRC Press.

Miller, R. K. (2004). Conversion of muscle to meat: Palatability. *Encyclopedia of Meat Sciences*, 256-266.

Minks, D., & Stringer, W. C. (1972). The influence of aging beef in vacuum. *Journal of Food Science*, *37*(5), 736-738.

Moore, M. C., Gray, G. D., Hale, D. S., Kerth, C. R., Griffin, D. B., Savell, J. W., Raines, C. R., Belk, K. E., Woerner, D. R., Tatum, J. D., Igo, J. L., VanOverbeke, D. L., Mafi, G. G., Lawrence, T. E., Delmore, R. J., Christensen, L. M., Shackelford, S. D., King, D. A., Wheeler, T. L., Meadows, L. R., & O'Connor, M. E. (2012). National Beef Quality Audit–2011: In-plant survey of targeted carcass characteristics related to quality, quantity, value, and marketing of fed steers and heifers. *Journal of Animal Science*, DOI: 10.2527/jas.2012-5550.

NAMP. (2010). *The meat buyer's guide* (6th ed.). Reston, VA: North American Meat Processors Association.

National Cattlemen's Beef Association. (2009a). The SIMPLYBEEF guide to Beef Alternative Merchandising: Section 4, 184 Beef Loin, Top Sirloin Butt. Centennial, CO: National Cattlemen's Beef Association. Available from <http://beefretail.org/CMDocs/BeefRetail/bam/bamtrainingmanualsec4.pdf%3E. Accessed 12 February 2012.

National Cattlemen's Beef Association. (2009b). The SIMPLYBEEF guide to Beef Alternative Merchandising: Section 5, 112A Beef Rib, Ribeye. Centennial, CO: National Cattlemen's Beef Association. Available from <http://beefretail.org/CMDocs/BeefRetail/bam/bamtrainingmanualsec5.pdf%3E. Accessed 12 February 2012.

Neely, T. R., Lorenzen, C. L., Miller, R. K., Tatum, J. D., Wise, J. W., Taylor, J. F., Buyck, M. J., Reagan, J. O., & Savell, J. W. (1998). Beef Customer Satisfaction: Role of cut, USDA quality grade, and city on in-home consumer ratings. *Journal of Animal Science*, *76*(4), 1027-1033.

Neely, T. R., Lorenzen, C. L., Miller, R. K., Tatum, J. D., Wise, J. W., Taylor, J. F., Buyck, M. J., Reagan, J. O., & Savell, J. W. (1999). Beef Customer Satisfaction: Cooking method and degree of doneness effects on the top round steak. *Journal of Animal Science*, *77*(3), 653-660.

Nishimura, T., Hattori, A., & Takahashi, K. (1995). Structural weakening of intramuscular connective tissue during conditioning of beef. *Meat Science*, *39*, 127-133.

Nishimura, T., Hattori, A., & Takahashi, K. (1996). Relationship between degradation of proteoglycans and weakening of the intramuscular connective tissue during post-mortem ageing of beef. *Meat Science*, *42*, 251-260.

Oreskovich, D. C., McKeith, F. K., Carr, T. R., Novakofski, J., & Bechtel, P. J. (1988). Effects of different aging procedures on the palatability of beef. *Journal of Food Quality*, *11*(2), 151-158.

Parrish, F. C., Jr., Boles, J. A., Rust, R. E., & Olson, D. G. (1991). Dry and wet aging effects on palatability attributes of beef loin and rib steaks from three quality grades. *Journal of Food Science*, *56*(3), 601-603.

Perry, N. (2012). Dry aging beef. *International Journal of Gastronomy and Food Science*, *1*(1), 78-80.

Savell, J. W. (2008a). Dry-Aging of Beef. Centennial, CO: National Cattlemen's Beef Assocation. Available from <http://beefresearch.org/CMDocs/BeefResearch/Dry Aging of Beef.pdf%3E. Accessed 12 February 2012.

Savell, J. W. (2008b). Executive Summary: Non-Conforming Beef Research Summit. Centennial, CO: National Cattlemen's Beef Association. Available from <http://beefresearch.org/CMDocs/BeefResearch/Non Conforming Beef.pdf%3E. Accessed 12 July 2012.

Savell, J. W., Lorenzen, C. L., Neely, T. R., Miller, R. K., Tatum, J. D., Wise, J. W., Taylor, J. F., Buyck, M. J., & Reagan, J. O. (1999). Beef Customer Satisfaction: Cooking method and degree of doneness effects on the top sirloin steak. *Journal of Animal Science*, *77*(3), 645-652.

Sitz, B. M., Calkins, C. R., Feuz, D. M., Umberger, W. J., & Eskridge, K. M. (2006). Consumer sensory acceptance and value of wet-aged and dry-aged beef steaks. *Journal of Animal Science*, *84*, 1221-1226.

Smith, G. C., Culp, G. R., & Carpenter, Z. L. (1978). Postmortem aging of beef carcasses. *Journal of Food Science*, *43*, 823-826.

Smith, R. D., Nicholson, K. L., Nicholson, J. D. W., Harris, K. B., Miller, R. K., Griffin, D. B., & Savell, J. W. (2008). Dry versus wet aging of beef: Retail cutting yields and consumer palatability evaluations of steaks from US Choice and US Select short loins. *Meat Science*, *79*(4), 631-639.

Sweeter, K. K., Wulf, D. M., & Maddock, R. J. (2005). Determining the optimum beef longissimus muscle size for retail consumers. *Journal of Animal Science*, *83*(11), 2598-2604.

Taylor, R. G., Geesink, G. H., Thompson, V. F., Koohmaraie, M., & Goll, D. E. (1995). Is Z-disk degradation responsible for postmortem tenderization? *J Anim Sci*, *73*(5), 1351-1367.

U.S. Department of Agriculture. (1997). United States standards for grades of carcass beef. Washington, DC: United States Department of Agriculture, Agricultural Marketing Service. Available from <http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELDEV3002979%3E. Accessed 15 March 2011.

U.S. Department of Agriculture. (2010). Institutional meat purchase specifications: fresh beef series 100. Washington, DC: United States Department of Agriculture, Agricultural Marketing Service. Available from

<http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELDEV3003281%3E. Accessed 15 March 2011.

Warren, K. E., & Kastner, C. L. (1992). A comparison of dry-aged and vacuum-aged beef strip loins. *Journal of Muscle Foods*, *3*, 151-157.

West, S. E., Nicholson, K. L., Nicholson, J. D. W., Griffin, D. B., Lawrence, T. E., Wasser, B. E., & Savell, J. W. (2011). Innovative retail merchandising strategies to accommodate for the growing trend of heavier carcass weights in the United States. *Meat Science*, *88*(4), 610-618.

Wu, F. Y., & Smith, S. B. (1987). Ionic strength and myofibrillar protein solubilization. *Journal of Animal Science*, *65*, 597-608.

APPENDIX A

TABLES

Table 1
Means and standard deviations (SD) of USDA Choice[a] beef carcass characteristics

Carcass characteristics	Choice	SD
Adjusted 12th rib fat thickness (cm)	1.5	0.8
Kidney, pelvic, and heart fat (%)	2.0	0.13
Ribeye area (cm^2)	100.2	8.8
Hot carcass weight (kg)	407.8	21.2
USDA yield grade	3.1	0.6
USDA quality grade[b]	420.0	13.0

[a] USDA (1997).
[b] USDA (1997) quality grade: USDA Choice = 400.

Table 2
Demographic background of consumer panelists (*n* = 107) for steak evaluations

Item	Frequency (%)
Age, years	
< 21	11.2
22-29	51.4
30-39	15.0
40-49	7.5
50-59	6.5
≥ 60	8.4
Income, US$	
< 20,000	44.9
20,000-29,000	4.7
30,000-39,000	6.5
40,000-49,000	4.7
50,000-59,000	9.3
≥ 60,000	29.0
Household size, number of people	
1	27.1
2	29.9
3	15.9
4	15.9
5	7.5
≥ 6	3.7
Work Status	
Not employed	10.3
Part-time	37.4
Full-time	29.0
Student	23.4
Gender	
Male	44.9
Female	55.1
Nationality	
White	90.7
American Indian	0.9
African American	2.8
Hispanic	5.6

Table 3

Least squares means ± SEM[a] of retail yields (%) for fabrication of ribeye rolls (n = 12) stratified by aging treatment

Item	URMIS[b]	Dry-aged	Wet-aged	P > F
Retail yield		Percentage		
Beef Ribeye Filet Boneless	1253	34.54b ± 0.74	41.79a ± 0.74	<0.0001
Beef Ribeye Cap Steak Boneless	1254	9.10b ± 0.34	14.63a ± 0.34	<0.0001
M. complexus steak		1.61b ± 0.11	2.03a ± 0.11	0.0104
Lean trimmings (90% lean)		2.44b ± 0.53	15.99a ± 0.53	<0.0001
Fat		14.32b ± 1.13	22.28a ± 1.13	<0.0001
Crust		20.94a ± 0.67	0.00b ± 0.67	<0.0001
Connective Tissue/Bone		1.30b ± 0.14	1.99a ± 0.14	0.0022
Cooler shrink		15.21a ± 1.13	0.00b ± 1.13	<0.0001
Purge		0.25b ± 0.10	0.81a ± 0.10	0.0007
Cut loss[c]		-0.02 ± 0.06	0.08 ± 0.06	0.2438
Bag		0.40 ± 0.02	0.40 ± 0.02	0.9491
Total saleable yield		47.69b ± 1.17	74.44a ± 1.17	<0.0001

[a] SEM = Standard error of the least squares means.

[b] URMIS = Uniform Retail Meat Identity Standards.

[c] Cut loss calculated by comparing recovered weight to initial cut weight taken on specific fabrication day.

a-b Means within the same row lacking a common letter differ (P < 0.05).

Table 4
Least squares means ± SEM[a] of retail yields (%) for fabrication of top sirloin butts(n = 12) stratified by aging treatment

Item	URMIS[b]	Dry-aged	Wet-aged	*P* > F
Retail yield		Percentage		
Beef Loin Top Sirloin Filet Boneless	1323	34.68b ± 1.13	42.09a ± 1.13	0.0001
Beef Loin Top Sirloin Cap Steak Boneless	1421	11.36b ± 0.59	13.89a ± 0.59	0.0059
Stew meat		2.84 ± 0.31	2.84 ± 0.31	0.9918
Lean trimmings (90% lean)		5.90b ± 0.40	14.82a ± 0.40	<0.0001
Fat		9.64b ±1.35	22.51a ± 1.35	<0.0001
Crust		22.15a ± 0.35	0.00b ± 0.35	<0.0001
Connective Tissue/Bone		0.45b ± 0.08	1.18a ± 0.08	<0.0001
Cooler shrink		13.64a ± 0.22	0.00b ± 0.22	<0.0001
Purge		0.59b ± 0.31	2.55a ± 0.31	0.0002
Cut loss[c]		0.00b ± 0.05	0.15a ± 0.05	0.0419
Bag		0.48a ± 0.02	0.39b ± 0.02	0.0009
Total saleable yield		54.78b ± 1.36	73.64a ± 1.36	<0.0001

[a] SEM = Standard error of the least squares means.
[b] URMIS = Uniform Retail Meat Identity Standards.
[c] Cut loss calculated by comparing recovered weight to initial cut weight taken on specific fabrication day.
a-b Means within the same row lacking a common letter differ ($P < 0.05$).

Table 5
Least squares means ± SEM[a] of number of steaks from fabrication of ribeye rolls (n = 12) and top sirloin butts (n = 12) stratified by aging treatment

Item	URMIS[b]	Dry-aged	Wet-aged	$P > F$
		Number of steaks cut		
Beef Ribeye Roll, Lip On				
Beef Ribeye Filet Boneless	1253	11.7 ± 0.3	11.8 ± 0.3	0.6748
Beef Ribeye Cap Steak Boneless	1254	4.0b ± 0.1	5.1a ± 0.1	<0.0001
Beef Loin, Top Sirloin Butt, Boneless				
Beef Loin Top Sirloin Filet Boneless	1323	12.1b ± 0.2	13.3a ± 0.2	0.0006
Beef Loin Top Sirloin Cap Steak Boneless	1421	4.6 ± 0.2	4.8 ± 0.2	0.2750

[a] SEM = Standard error of the least squares means.
[b] URMIS = Uniform Retail Meat Identity Standards.
a-b Means within the same row lacking a common letter differ ($P < 0.05$).

Table 6

Least squares means and standard errors of the least squares means (SEM) for steak length and width measurements of USDA Choice[a] steaks stratified by aging treatment × muscle

Interaction effects	Steak Length (cm)	Steak Width (cm)
Dry-aged, *M. spinalis thoracis*	7.83fg	12.84b
Dry-aged, *M. longissimus thoracis*	8.45ef	6.47e
Dry-aged, *M. gluteobiceps*	13.40b	3.96f
Dry-aged, *M. gluteus medius*	8.76e	6.32e
Wet-aged, *M. spinalis thoracis*	6.96g	15.05a
Wet-aged, *M. longissimus thoracis*	9.47d	6.89d
Wet-aged, *M. gluteobiceps*	16.20a	4.24f
Wet-aged, *M. gluteus medius*	10.68c	7.51c
$P > F$	<0.0001	<0.0001
RMSE[b]	5.9	3.0

[a] USDA (1997).

[b] RMSE=Root Mean Square Error from Analysis of Variance.

a-g Means within the same column lacking a common letter differ ($P < 0.05$).

Table 7
Least squares means and standard errors of the least squares means (SEM) for steak portion weights of USDA Choice[a] steaks stratified by aging treatment and muscle

Main effects	Portion Weight (g)	SEM
Aging Treatment		
Dry-aged	169.76b	2.7
Wet-aged	204.19a	2.5
P > F	<0.0001	
Muscle		
M. longissimus thoracis	215.30a	2.7
M. spinalis thoracis	168.31c	4.4
M. gluteus medius	198.55b	2.7
M. gluteobiceps	165.73c	4.4
P > F	<0.0001	

[a] USDA (1997).
a-c Means within the same column lacking a common letter differ ($P < 0.05$).

Table 8
Least squares means and standard errors of the least squares means (SEM) for cooking times, cooking yields, and cooking temperatures of USDA Choice[a] steaks used for consumer evaluation stratified by aging treatment and muscle

Main effects	Total Cook Time (minutes)	Cook Yield (%)	Internal Temperature Endpoint (ºC)
Aging Treatment			
Dry-aged	24.6	84.06a	70.18
Wet-aged	23.8	79.67b	70.25
$P > F$	0.5633	<0.0001	0.3689
SEM	1.0	0.73	0.06
Muscle			
M. longissimus thoracis	26.3a	82.62	70.21
M. spinalis thoracis	24.4a	83.40	70.20
M. gluteus medius	27.8a	80.99	70.32
M. gluteobiceps	18.5b	80.44	70.15
$P > F$	<0.0001	0.1545	0.4945
SEM	1.4	1.04	0.08

[a] USDA (1997).
a-b Means within the same column lacking a common letter differ ($P < 0.05$).

Table 9
Least squares means for consumer sensory responses (n = 108 consumers) of USDA Choice [a] steaks stratified by aging treatment and muscle

Main effects	Level of beef flavor[b]	Tenderness like[c]	Level of tenderness[d]	Juiciness Like[c]	Level of juiciness[e]
Aging Treatment					
Dry-aged	6.2	6.9	6.9	6.2b	6.1
Wet-aged	6.2	7.1	7.0	6.5a	6.2
$P > F$	0.9377	0.0901	0.2589	0.0383	0.2334
Muscle					
M. spinalis thoracis	6.6a	8.1a	8.1a	7.4a	7.3a
M. longissimus thoracis	5.9c	6.7b	6.8b	6.0c	5.8c
M. gluteobiceps	6.3ab	6.9b	6.9b	6.5b	6.4b
M. gluteus medius	6.1bc	6.1c	5.9c	5.5d	5.1d
$P > F$	0.0036	<0.0001	<0.0001	<0.0001	<0.0001
RMSE [f]	3.8	4.5	4.3	3.5	3.2

[a] Choice.
[b] 10=Extremely flavorful or intense; 1=extremely bland or no flavor.
[c] 10=Like extremely; 1=dislike extremely.
[d] 10=Extremely tender; 1=extremely tough.
[e] 10=Extremely juicy; 1=extremely dry.
[f] RMSE = Root Mean Square Error from Analysis of Variance
a-d Means within the same column lacking a common letter differ ($P < 0.05$).

Table 10
Least squares means for consumer sensory responses (n = 108 consumers) of USDA Choice[a] steaks stratified by aging treatment × muscle

Interaction effects	Overall like[b]	Flavor like[b]	Level of flavor[c]	Beef flavor like[b]
Aging treatment ×muscle				
Dry-aged, *M. spinalis thoracis*	6.4b	6.0b	6.4b	6.2b
Wet-aged, *M. spinalis thoracis*	7.4a	7.1a	7.0a	7.1a
Dry-aged, *M. longissimus thoracis*	6.0bcd	6.0b	5.9bc	6.1b
Wet-aged, *M. longissimus thoracis*	6.2bc	6.0b	5.7c	6.1b
Dry-aged, *M. gluteobiceps*	5.6d	5.3c	6.0bc	5.5c
Wet-aged, *M. gluteobiceps*	6.3b	5.9b	6.1bc	6.2b
Dry-aged, *M. gluteus medius*	5.6d	5.6bc	6.2bc	5.8bc
Wet-aged, *M. gluteus medius*	5.7cd	5.7bc	5.6c	5.9bc
$P > F$	0.0317	0.0220	0.0252	0.0396
RMSE[d]	3.5	3.3	3.9	3.9

[a] Choice.
[b] 10=Like extremely; 1=dislike extremely.
[c] 10=Extremely flavorful or intense; 1=extremely bland or no flavor.
[d] RMSE = Root Mean Square Error from Analysis of Variance
a-d Means within the same column lacking a common letter differ ($P < 0.05$).

Table 11

Least squares means and standard errors of the least squares means (SEM) for cooking times, cooking yields, and cooking temperatures of USDA Choice[a] steaks used for trained panel evaluation stratified by aging treatment and muscle

Main effects	Total Cook Time (minutes)	Cook Yield (%)	Internal Temperature Endpoint (ºC)
Aging Treatment			
Dry-aged	21.0	82.13	70.28
Wet-aged	20.6	80.49	70.11
$P > F$	0.7399	0.3150	0.4525
SEM	0.8	1.15	0.16
Muscle			
M. longissimus thoracis	22.6b	83.03	70.02
M. spinalis thoracis	17.3c	82.60	70.52
M. gluteus medius	28.3a	77.99	70.24
M. gluteobiceps	15.3c	81.61	70.00
$P > F$	<0.0001	0.1163	0.3207
SEM	1.2	1.6	0.22

[a] USDA (1997).

a-c Means within the same column lacking a common letter differ ($P < 0.05$).

Table 12

Least squares means for trained sensory responses of USDA Choice[a] steaks stratified by aging treatment and muscle

Main effects	Fat-like	Metallic
Aging Treatment		
Dry-aged	2.22	3.14a
Wet-aged	2.35	2.94b
P > F	0.1804	0.0251
Muscle		
M. spinalis thoracis	3.40a	2.75b
M. longissimus thoracis	1.98b	2.89b
M. gluteobiceps	2.13b	3.15a
M. gluteus medius	1.63c	3.35a
P > F	<0.0001	<0.0001
RMSE[b]	0.21	0.17

[a] USDA (1997).

[b] RMSE=Root Mean Square Error from Analysis of Variance.

a-d Means within the same column lacking a common letter differ ($P < 0.05$).

Table 13

Least squares means for trained sensory responses of USDA Choice[a] steaks stratified by aging treatment × muscle

Interaction effects	Beef Flavor	Brown Roasted	Bloody/ Serumy	Musty	Putrid	Warmed Over Flavor
Aging treatment ×muscle						
Dry-aged, *M. spinalis thoracis*	5.32c	2.15d	2.27b	3.01a	3.56a	0.01cd
Wet-aged, *M. spinalis thoracis*	7.05b	2.75b	2.98a	0.65d	0.36c	0.24ab
Dry-aged, *M. longissimus thoracis*	6.51b	2.71bc	2.36b	1.67bc	1.55b	0.26a
Wet-aged, *M. longissimus thoracis*	7.85a	3.42a	2.47b	0.42d	0.11c	0.07bcd
Dry-aged, *M. gluteobiceps*	5.45c	2.25cd	2.65ab	2.09b	2.81a	0.08bcd
Wet-aged, *M. gluteobiceps*	6.76b	2.87b	2.51b	0.74d	0.21c	0.00d
Dry-aged, *M. gluteus medius*	6.73b	2.92b	2.38b	1.26c	1.25b	0.04cd
Wet-aged, *M. gluteus medius*	7.20a	2.72bc	2.99a	0.31d	0.10c	0.17abc
$P > F$	0.0372	0.0358	0.0310	0.0052	0.0007	0.0043
RMSE[b]	0.59	0.37	0.32	0.49	0.95	0.05

[a] USDA (1997).

[b] RMSE=Root Mean Square Error from Analysis of Variance.

a-d Means within the same column lacking a common letter differ ($P < 0.05$).

APPENDIX B

1. Carcass collection sheet
2. Ribeye cutting sheet
3. Top sirloin butt cutting sheet
4. Steak measurement sheet
5. Consumer cooking record
6. Consumer consent form
7. Consumer demographic form
8. Consumer ballot
9. Trained sensory cooking record
10. Trained ballot

BAM Aging - Carcass Collection

Recorder A. Smith

Study No. BAM Aging

TAG ID	Animal ID (Seq)	LOT	Kill Date	HCW	Marb Sc.	Lean Mat	Skel. Mat	QG	PYG/APYG	KPH	REA	Act YG	Gender
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													

Entered:	
Checked:	

Date: ______________________

SUBPRIMAL: Ribeye Rolls (112A)

Aging Type   Subprimal #   Cutter: D. Griffin

Recorder: ______

Initial Cut Weight_______________

--

Yield

Initial Weight (in bag)

____

Bag Weight

____

Purge Weight

____

Retail Cuts

Filets # of Cuts____ wt.__________

Cap Steaks # of Cuts____ wt.__________

Complexus # of Cuts____ wt.__________

Heavy Connective Tissue/Bone wt.______________

Scab wt. _________

Lean Trim wt. __________

Fat Trim wt. ____________

Total Weight ___________

%_________

Notes:

Entered:
Checked:

Date: ______________________

SUBPRIMAL: Top Sirloin Butt (184)

Aging Type   Subprimal #

Cutter: D. Griffin

Recorder: ______

Initial Cut Weight_______________

Yield

Initial Weight (in bag) _____________

Bag Weight _______________

Purge Weight _____________

Out-of-Bag Weight ________________

Retail Cuts

Filets # of Cuts____ wt._______________

Cap Steaks # of Cuts____ wt._______________

Stew Meat wt._______________

Heavy Connective Tissue/Bone wt._______________

Scab wt. _____________

Lean Trim wt. _____________

Fat Trim wt. _____________

Total Weight ______________

%_____________

Notes:

BAM Aging Study

Steak Measurements

Cx #	Side	Aging	Subprimal	Steak Type	Steak #	Length (cm)	Width (cm)	Weight (g)

Entered By:_____________ Recorded By:___________

Checked By:_____________ Date:_____________

BAM Aging Study - 2012

Consumer Sensory - Cooking Record

Recorded By: Date:

Subprimal #	Steak Type	Random #	Raw Weight (g)	Raw Temp (ºC)	Start Time (military)	Removal Time (military)	Final Temp (ºC)	Final Weight (g)

Entered by:_________ Checked By:_____________

Date:______________ Date:____________________

TEXAS A&M UNIVERSITY HUMAN SUBJECTS PROTECTION PROGRAM

CONSENT FORM

Project Title: Dry versus wet aging of beef: Retail cutting yields and palatability evaluations of steaks using innovative cutting styles

You are being invited to take part in a research study being conducted by Texas A&M University. You are being asked to read this form so that you know about this research study. The information in this form is provided to help you decide whether or not to take part in the research. If you decide to take part in the study, you will be asked to sign this consent form. If you decide you do not want to participate, there will be no penalty to you, and you will not lose any benefit you normally would have.

WHY IS THIS STUDY BEING DONE?
The purpose of this study is to: Determine differences in flavor and texture of steaks that were exposed to different aging treatments.

WHY AM I BEING ASKED TO BE IN THIS STUDY?
You are being asked to be in this study because you consume beef.

HOW MANY PEOPLE WILL BE ASKED TO BE IN THIS STUDY?
100-120 people (participants) will be enrolled in this study.

WHAT ARE THE ALTERNATIVES TO BEING IN THIS STUDY?
The alternative is not to participate.

WHAT WILL I BE ASKED TO DO IN THIS STUDY?
Your participation in this study will last up to 1 hour and includes 1 visit. The procedures you will be asked to perform are described below.

Consumer will sit in sensory booth and eat 5 beef samples and then complete a questionnaire based on their opinion of the product.

ARE THERE ANY BENEFITS TO ME?
There no direct benefit to you by being in this study. What the researchers find out from this study may help retailers and members of the foodservice industry make more informed decisions regarding the aging style of their products.

WILL THERE BE ANY COSTS TO ME?
Aside from your time (about one hour), there are no costs for taking part in the study.

WILL I BE PAID TO BE IN THIS STUDY?
Consumers who are not currently employed by the Texas A&M University System will be compensated with $20.00 at the conclusion of the experiment. The consumers will complete a W-9 to be processed as a one-time payment through Texas A&M University.

WILL INFORMATION FROM THIS STUDY BE KEPT PRIVATE?
The records of this study will be kept private. No identifiers linking you to this study will be included in any sort of report that might be published. Research records will be stored securely

and only Dr. Jeffrey Savell, Dr. Rhonda Miller, and Ms. Amanda Smith will have access to the records.

Information about you will be stored in locked file cabinet; computer files will be encrypted and protected with a password. This consent form will be filed securely in a locked laboratory with limited access to those mentioned above.

Information about you will be kept confidential to the extent permitted or required by law. People who have access to your information include the Principal Investigator and research study personnel. Representatives of regulatory agencies such as the Office of Human Research Protections (OHRP) and entities such as the Texas A&M University Human Subjects Protection Program may access your records to make sure the study is being run correctly and that information is collected properly.

WHOM CAN I CONTACT FOR MORE INFORMATION?
You can call the Principal Investigator to tell him about a concern or complaint about this research study. The Principal Investigator Dr. Jeffrey Savell can be called at 979-845-3935 or emailed at j-savell@tamu.edu. You may also contact the project coordinator, Ms. Amanda Smith at 979-255-1079 or amandasmith10@gmail.com.

For questions about your rights as a research participant; or if you have questions, complaints, or concerns about the research and cannot reach the Principal Investigator or want to talk to someone other than the Investigator, you may call the Texas A&M Human Subjects Protection Program office.

- Phone number: (979) 458-4067
- Email: irb@tamu.edu

MAY I CHANGE MY MIND ABOUT PARTICIPATING?
You have the choice whether or not to be in this research study. You may decide not to participate or stop participating at any time. If you choose not to be in this study, there will be no effect. You can stop being in this study at any time with no effect.

By participating in the sensory evaluation, you are giving permission for the investigator to use your information for research purposes.

Thank you.

Dr. Jeffrey Savell

Panelist Demographic Information

Fill out the following information by placing an x in the correct box.

1. Please indicate your age by marking the appropriate blank:
   ___Under 21 years
   ___22-29 years
   ___30-39 years
   ___40-49 years
   ___50-59 years
   ___60 years or older

2. Please indicate your income (combined income if both you and your spouse are employed) by marking the appropriate blank:
   ___Under $20,000
   ___$20,000-29,000
   ___$30,000-39,000
   ___$40,000-49,000
   ___$50,000-59,000
   ___$60,000 or more

3. Please indicate your household size, including yourself:
   ___1
   ___2
   ___3
   ___4
   ___5
   ___6 or more

4. Please indicate your current working status:
   ___Not employed
   ___Part-time
   ___Full-time
   ___Student

5. Please indicate your sex:
   ___Male
   ___Female

6. Please indicate your ethnic background:
   ___White
   ___Black
   ___Hispanic
   ___American Indian
   ___Asian or Pacific Islander

Participant Number ______- **Group Time____________**
Sample Number ________ **Date__________________**

1. Indicate by a mark in the box your **OVERALL LIKE/DISLIKE** of the meat sample.

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike Extremely				No Preference				Like Extremely

2. Indicate by placing a mark in the box your **LIKE/DISLIKE** for the **FLAVOR** of the meat sample.

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike Extremely				No Preference				Like Extremely

3. Indicate by placing a mark in the box how you feel about the **LEVEL** of **FLAVOR**.

☐	☐	☐	☐	☐	☐	☐	☐	☐
Extremely Bland or No Flavor				No Difference				Extremely Flavorful

4. Indicate by placing a mark in the box your **LIKE/DISLIKE** for the **BEEFY FLAVOR** of the meat sample**.**

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike Extremely				No Difference				Like Extremely

5. Indicate by placing a mark in the box how you feel about the **LEVEL** of **BEEFY FLAVOR** for the meat product.

☐	☐	☐	☐	☐	☐	☐	☐	☐
Extremely Bland or No Flavor				No Difference				Extremely Flavorful

6. Indicate by placing a mark in the box your **LIKE/DISLIKE** for the **TENDERNESS** of the meat product.

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike Extremely				No Preference				Like Extremely

7. Indicate by placing a mark in the box your **LEVEL** of **TENDERNESS** of the meat product.

☐	☐	☐	☐	☐	☐	☐	☐	☐
Extremely Tough				Neither Tough or Tender				Extremely Tender

8. Indicate by placing a mark in the box your **LIKE/DISLIKE** for the **JUICINESS** of the meat product.

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike Extremely				No Preference				Like Extremely

Participant Number _____- **Group Time____________**
Sample Number _________ **Date___________________**

9. Indicate by placing a mark in the box how you feel about the **LEVEL** of **JUICINESS** of the meat product.

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Extremely Dry	Neither Dry or Juicy	Extremely Juicy

Cook Data

Project: Dry Aged vs Wet Aged **Date:** ____________ ______ **Page:** ___/2___

Random Number										
Order										
#-Type										
TRT										
Raw Weight										
Cooked Weight										
Temp On										
Time On										
Temp Off										
Time Off										

Recorder: ________ **Entered by:** ________ **Date:** ________

Checked by: ________ **Date:** ________

Name: ______________________ Date: ______________________ A.M.S. 12-

Flavor Attributes	Sample ID								
Beef Flavor ID									
Brown/Roasted									
Bloody/Serumy									
Fat-Like									
Metallic									
Liver-Like									
Umami									
Overall Sweet									
Sweet									
Sour									
Salty									
Bitter									
Sour Aromatics									
Green-haylike									
Other Notes									
Barnyard									
Animal Hair									
Burnt									
Heated Oil									
Chemical									
Apricot									
Asparagus									
Cumin									
Floral									
Beet									
Chocolate/Cocoa									
Green-Grass									
Musty-Earthy/Humus									
Medicinal									
Petroleum-like									
Smokey Charcoal									
Smokey Wood									
Spoiled-Putrid									
Dairy									
Buttery									
Cooked Milk									
Sour milk/Sour Dairy									
Refigerator Stale									
Warmed-Over									
Soapy									
Painty									
Fishy									
Cardboardy									
Aftertaste-Barnyard									
Aftertaste-Bitter									
Aftertaste-Musty-Earthy Humus									
Aftertaste-Spoiled/Putrid									
Aftertaste-Sour									
Aftertaste-Metallic									

0 * 1 * 2 * 3 * 4 * 5 * 6 * 7 * 8 * 9 * 10 * 11 * 12 * 13 * 14 * 15

Slight | Moderate | Strong